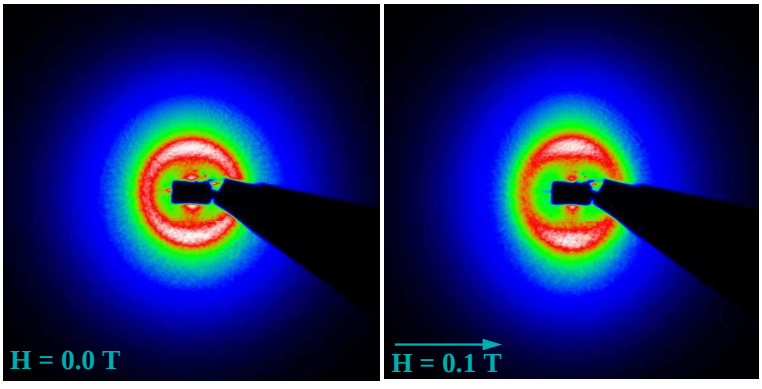
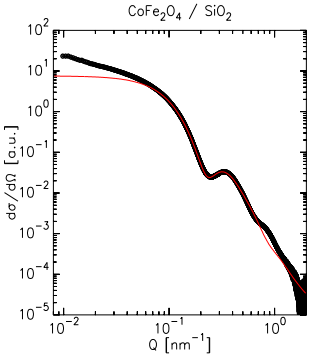
ESRF	**Experiment title:** Structure and Dynamics of Colloidal Liquids and Crystals with Magnetic Dipole-Dipole Interaction	**Experiment number:** SC-1067
Beamline: ID10/ID02	**Date of experiment:** from: 20.11.02/4.10.02 to: 26.11.02/7.10.02	**Date of report:** 24.02.02
Shifts: 18/9	**Local contact(s):** A.Robert / T. Narayanan	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):
Joachim Wagner[1*],Tina Autenrieth[1*],Gerhard Grübel[2*]
[1]Universität des Saarlandes, Physikalische Chemie, Saarbrücken (Germany)
[2]ESRF, Grenoble (France)

Report:

As a continuation of proposal SC-891, the structural and dynamic properties of magnetic colloidal particles were studied employing small angle X-Ray scattering. The particles consist of a magnetic core of $CoFe_2O_4$ surrounded by a SiO_2 shell. Different to the former experiments, we succeeded to prepare smaller particles with a thinner shell ($\sigma_{tot} = 42\,nm$) but with a somewhat higher polydispersity of 0.056. Due to the smaller interdistances of the magnetic cores, the magnetic contribution to the interaction potential is significantly higher than in the former experiment, because it is proportional to the inverse third power of the interdistance. For this reason, we could observe significant changes of the liquid-like structure factors in dependence of an external magnetic field even at less than one millitesla. This is evident from the anisotropy of the 2D scattering pattern.



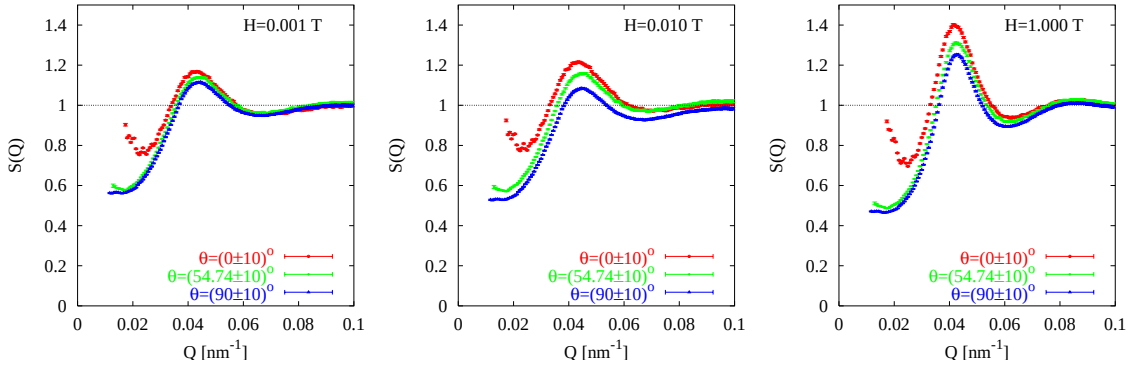


In presence of an external magnetic field the magnetic dipoles arrange parallel to the field direction. In this situation, the dipoles $\vec{\mu}_i$ and $\vec{\mu}_j$ become equal in terms of modulus and orientation.

As consequence, the dipole-dipole interaction depends only on the interdistance r_{ij} and the angle $\theta = \angle(\vec{\mu}_i \vec{r}_{ij})$.

$$V_{ij} = \frac{4\pi}{\mu_0}\left[\frac{\vec{\mu}_i\vec{\mu}_j}{r_{ij}^3} - 3\frac{(\vec{\mu}_i\vec{r}_{ij})(\vec{\mu}_j\vec{r}_{ij})}{r_{ij}^5}\right] = \frac{4\pi\mu_i^2}{\mu_0 r_{ij}^3}\left[1 - 3\cos^2\theta\right] \qquad (1)$$

The term $1 - 3\cos^2\theta$ equals (i) -2 (attractive) for $\vec{r}_{ij} \parallel \vec{H}$, (ii) equals 1 (repulsion) for $\vec{r}_{ij} \perp \vec{H}$ and (iii) vanishes at the magic angle $\theta = \arccos\sqrt{1/3}$, i.e. in this case we expect no magnetic contribution to the interaction potential. This becomes evident from the sector averages and the corresponding structure factors for these directions. The structure factor resulting from the magic sector lies in between of the directions parallel and perpendicular to the external field. Even at fields as low as $1\,mT$, small effects could be observed for the small particles with a total diameter of $\sigma = 42\,nm$.



For the reason of intensity, we used slightly larger particles ($\sigma = 70\,nm$) for XPCS experiments, which lead — as expected — only to small structural changes in dependence of the external field. Nevertheless, we were able to measure Q-dependent dynamic structure factors $D_0/D_{eff}(Q)$ for zero field and different directions at $1\,T$. The influence to the collective diffusion is much more pronounced than the influence to the static structure factor. This is to our knowledge the first experimental access to collective diffusion in magnetic colloids at mesoscopic length scales.